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Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Atmospheric Infrared Sounder (AIRS) Project Status

September 26, 2006

T. Pagano
AIRS Project Office
Jet Propulsion Laboratory

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Agenda

- Meeting Agenda/Logistics
- Standard Product Status
- Weather Forecast Improvement
- Key Science Investigations
- Science Team and Awards
- ARIES Future Mission Concept
  - Builds on AIRS and MODIS
- Summary and Conclusions

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AIRS/AMSU/HSB Standard Products

Radiance Products (Level 1B)	RMS Requirement	Current Estimate
AIRS IR Radiance	3%*	<0.2%
AIRS VIS/NIR Radiance	20%	10-15%
AMSU Radiance	0.25-1.2 K	1-2 K
HSB Radiance	1.0-1.2 K	N/A
Standard Core Products (Level 2)		
Cloud Cleared IR Radiance	1.0 K	<1.0 K
Sea Surface Temperature	0.5 K	0.8 K
Land Surface Temperature	1.0 K	TBD (V5)
Temperature Profile	1 K / km	1K / km
Humidity Profile	15% / 2 km	15% / 2km
Total Precipitable Water	5%	5%
Fractional Cloud Cover	5%	TBD (V5)
Cloud Top Height	0.5 km	TBD (V5)
Cloud Top Temperature	1.0 K	TBD (V5)
Total Ozone Column	-	5%
Ozone Profile	-	TBD (V5)
Carbon Monoxide	-	TBD (V5)
Methane	-	TBD (V5)

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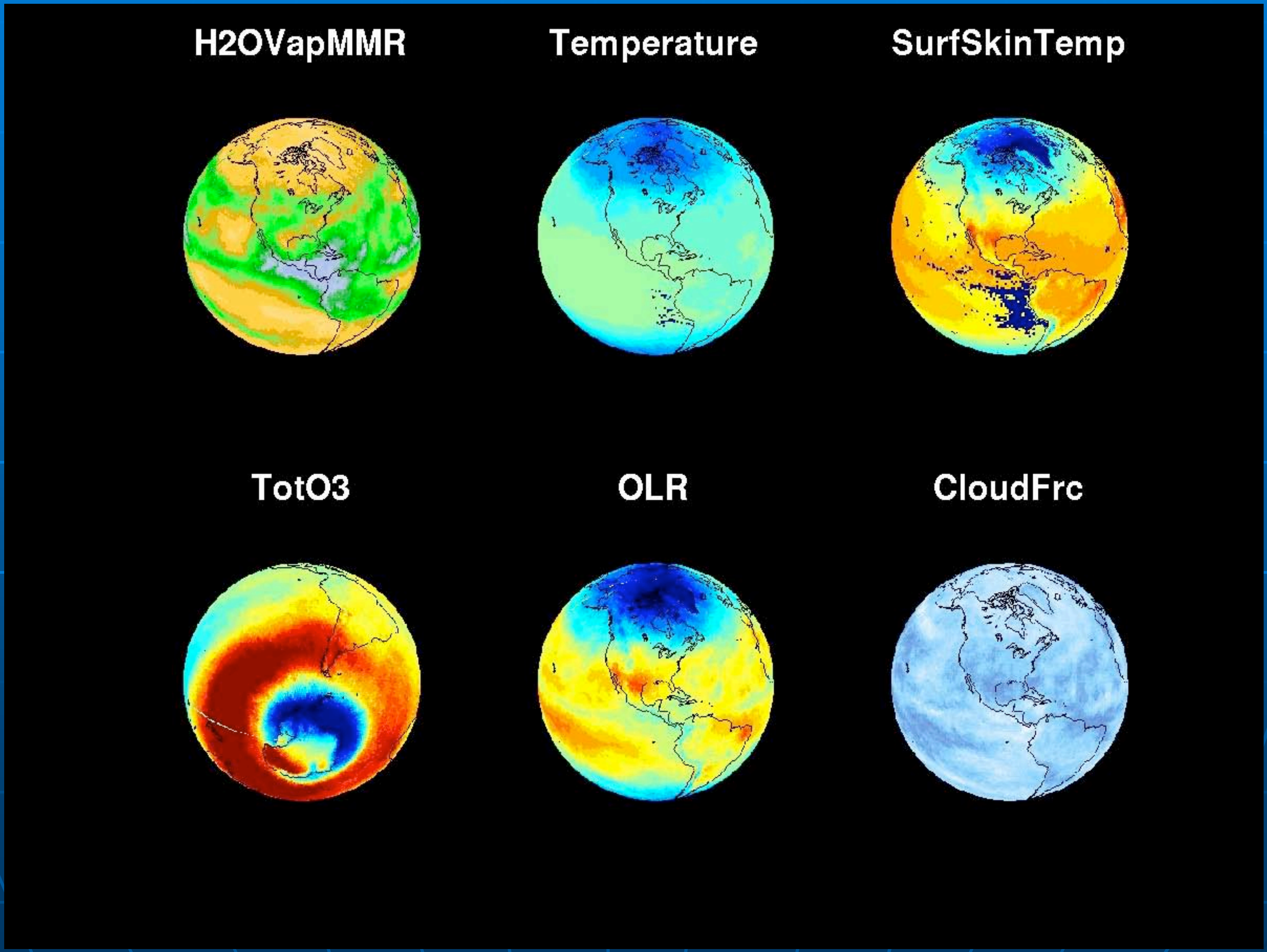
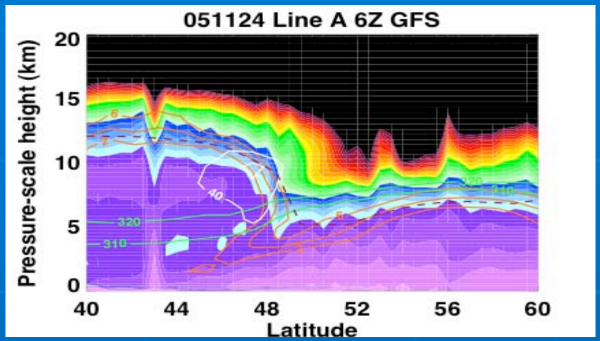
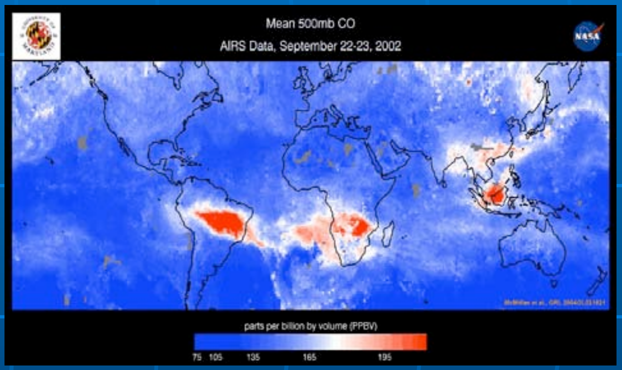
AIRS Level 3 Products online for V4

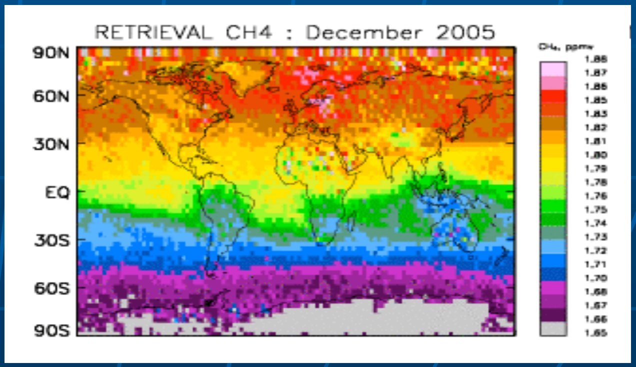


3 New Standard Products for Version 5

- Ozone Profile
  - Good sensitivity, but use wisely!
  - Bian, J., A. Gettelman, H. Chen, and L. L. Pan, Validation of satellite ozone profile retrievals using Beijing ozonesonde data, JGR, in review
  - Pan, L.L., J.C Wei, C. Barnet, A. Gettelman, W. J. Randel, R. Gao, E.V. Browell, and O. Cooper, Validation of AIRS ozone profile in the upper troposphere and lower stratosphere using airborne in situ measurements, to be submitted.
  - Monahan, K., L. L. Pan, J. C. Wei, A. McDonald, G. Boderker, Validation of AIRS ozone product using ozonesodes from Lauder, New Zealand and Boulder, USA., in preparation. 2006
- Carbon Monoxide Profile
  - Well validated; ready for science use.
  - McMillan, W. W., et al. (2005), Daily global maps of carbon monoxide from NASA's Atmospheric Infrared Sounder, Geophysical Research Letters, 32. L11801
- Methane Profile
  - Development complete. Limited Validation!
  - Validation underway by NOAA







AIRS Forecast Improvement

John LeMarshall (JCSDA)

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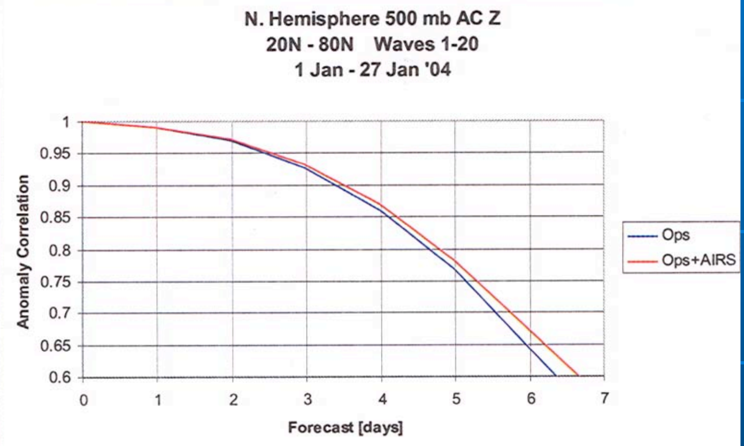
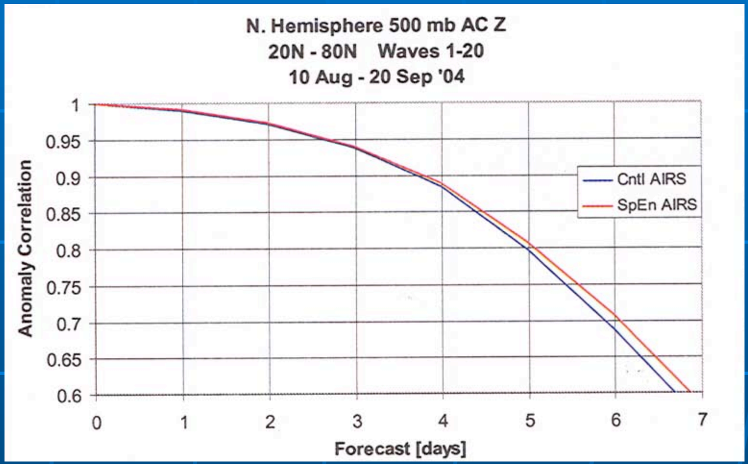
Improved Forecast Prediction
1 in 18 AIRS FOV's
(6 hours in 6 Days)
Northern Hemisphere
October 2004 *



Additional Improvement Using
All 18 AIRS FOV's
(11 hours total in 6 Days)
Northern Hemisphere
Preliminary



"This AIRS instrument has provided the most significant increase in forecast improvement in this time range of any other single instrument,"** ***Retired Navy Vice Admiral Conrad C. Lautenbacher, Jr., Ph.D., under secretary of commerce for oceans and atmosphere and NOAA administrator.

J. LeMarshall, J. Jung, J. Derber, R. Treadon, S. Lord, M. Goldberg, W. Wolf, H. Liu, J. Joiner, J. Woollen, R. Todling, R. Gelaro "Impact of Atmospheric Infrared Sounder Observations on Weather Forecasts", EOS, Transactions, American Geophysical Union, Vol. 86 No. 11, March 15, 2005

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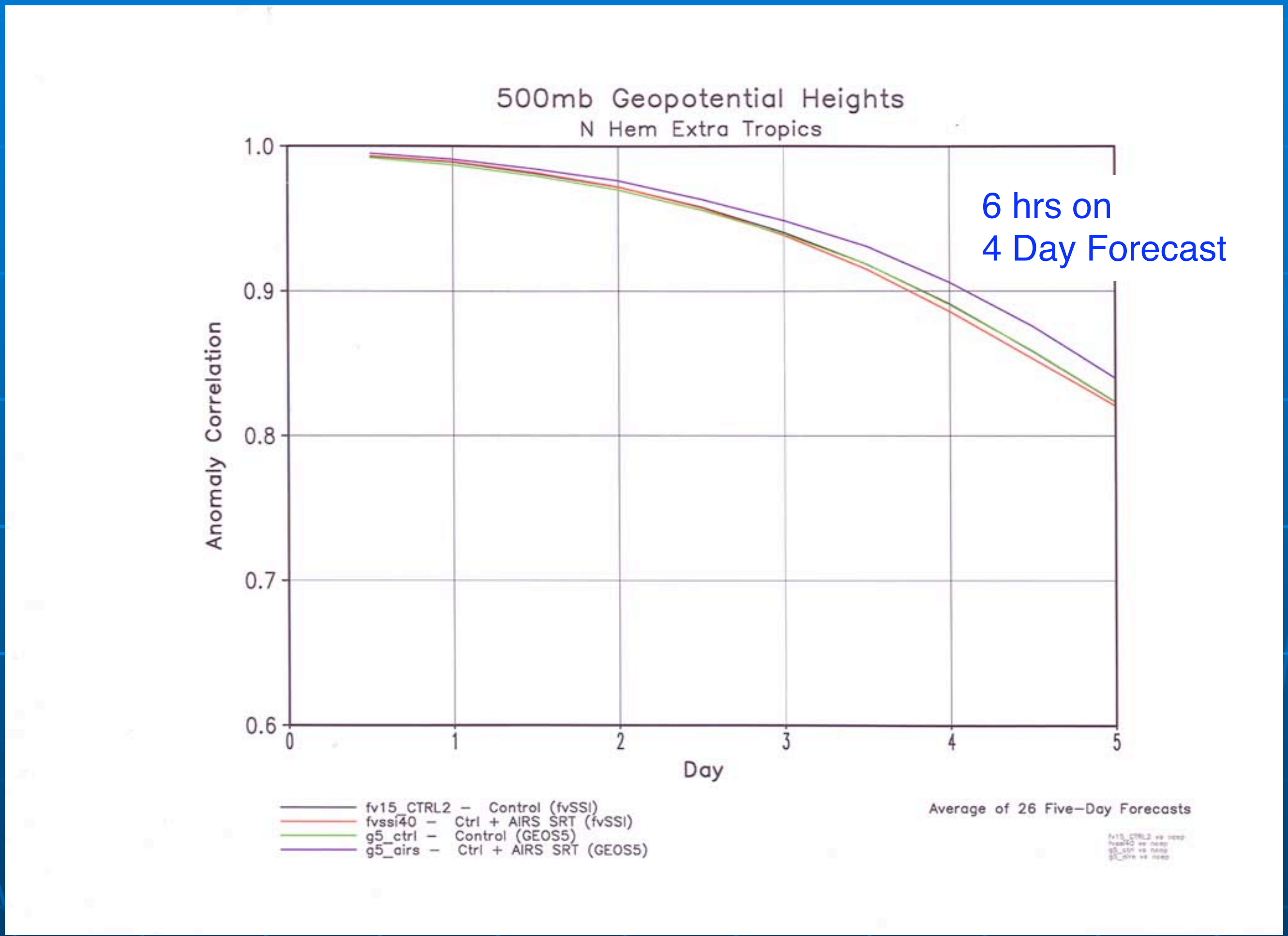
Good Forecast Impact with L2 using AIRS T(p), q(p)



Oreste Reale: Goddard Laboratory for Atmospheres
GEOS-5 by GMAO

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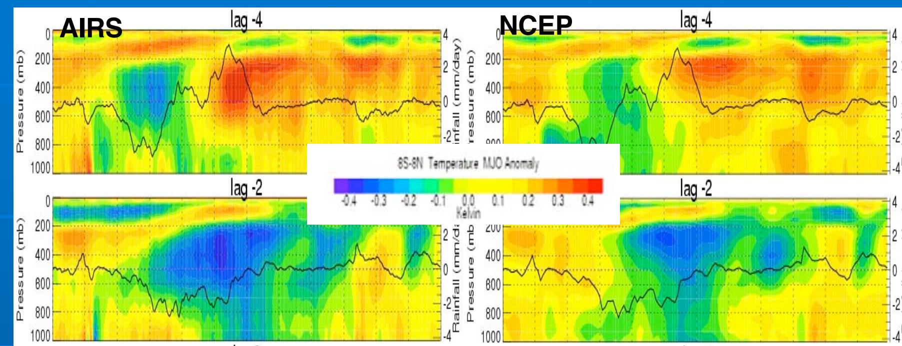
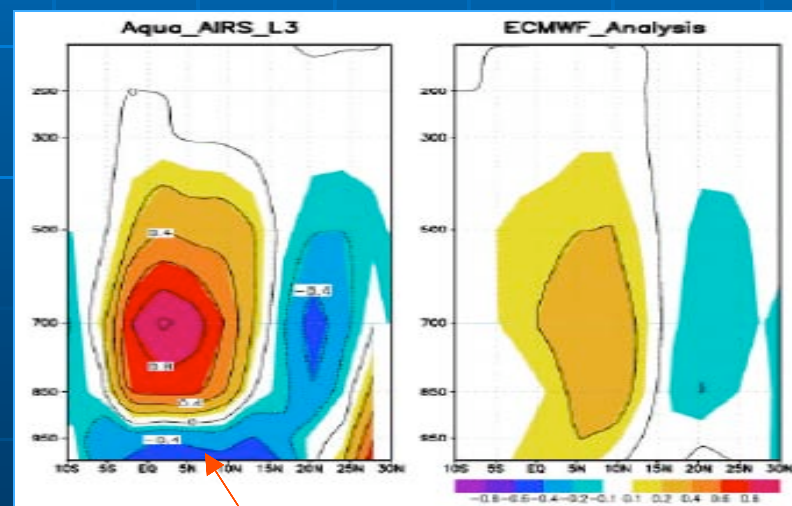
AIRS Temperature and Water Vapor Used to Study Global Weather Patterns

- **Madden Julian Oscillation (MJO)**
  - Major Differences in T and Q in lower troposphere between AIRS and NCEP
  - Convection preceded by warm and moist anomaly
  - Tian, B., D. E. Waliser, E. Fetzer, B. Lambrigtsen, Y. Yung, and B. Wang 2005: Vertical Moist Thermodynamic Structure and Spatial-temporal Evolution of the Madden-Julian Oscillation in Atmospheric Infrared Sounder Observations. J. Atmos. Sci
- **Monsoon Interseasonal Waves (MISO)**
  - Larger moisture perturbations compared to ECMWF & NCEP reanalysis.
  - Boundary-layer moistening ahead of the convection preconditions the northward movement of MISO.
  - Positive SST anomaly is the major factor for the BL moistening in this period.
  - Xiouhua Fu, Bin Wang, Li Tao, Satellite data reveal the 3-D moisture structure of Tropical Intraseasonal Oscillation and its coupling with underlying ocean, Geophys Res. Lett. VOL. 33, L03705, doi:10.1029/2005GL025074, 2006





Surface Dry Zone

H_2O

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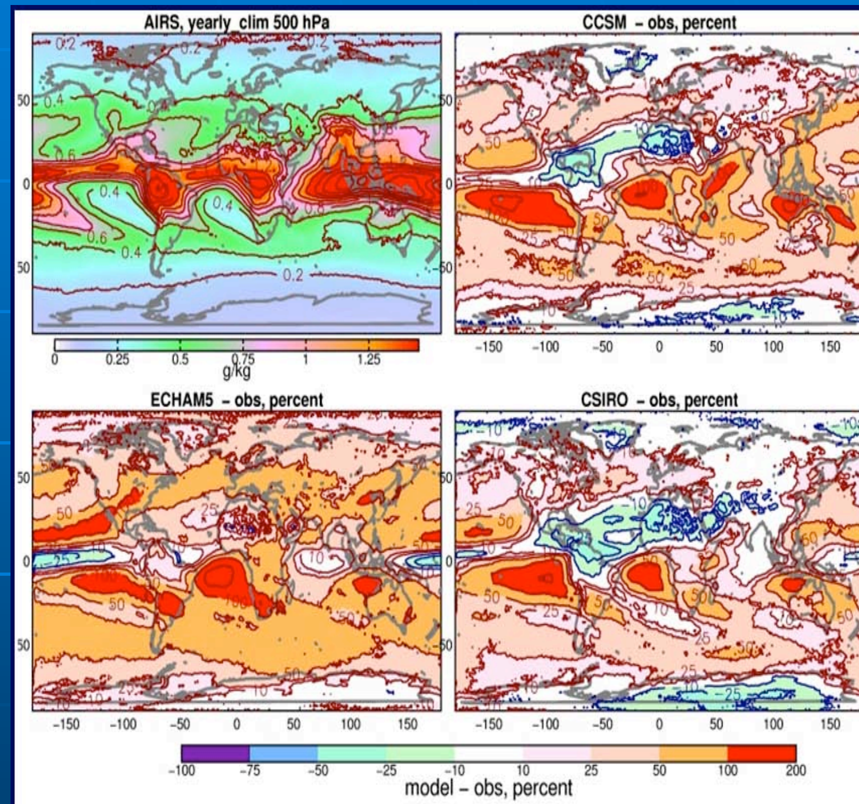
AIRS Water Vapor used to Validate Climate Models

- "Three-dimensional tropospheric water vapor in coupled climate models compared with observations from the AIRS satellite system",
  - D. Pierce, T. Barnett (Scripps)
  - Accepted GRL, 2006
  - Models show >50% bias errors in H2O vapor. Models worst at mid altitude and mid latitude.
  - "Analysis of the accuracy and sampling biases of the AIRS measurements suggests that these differences are due to systematic model errors, which might affect the model-estimated range of climate warming anticipated over the next century."



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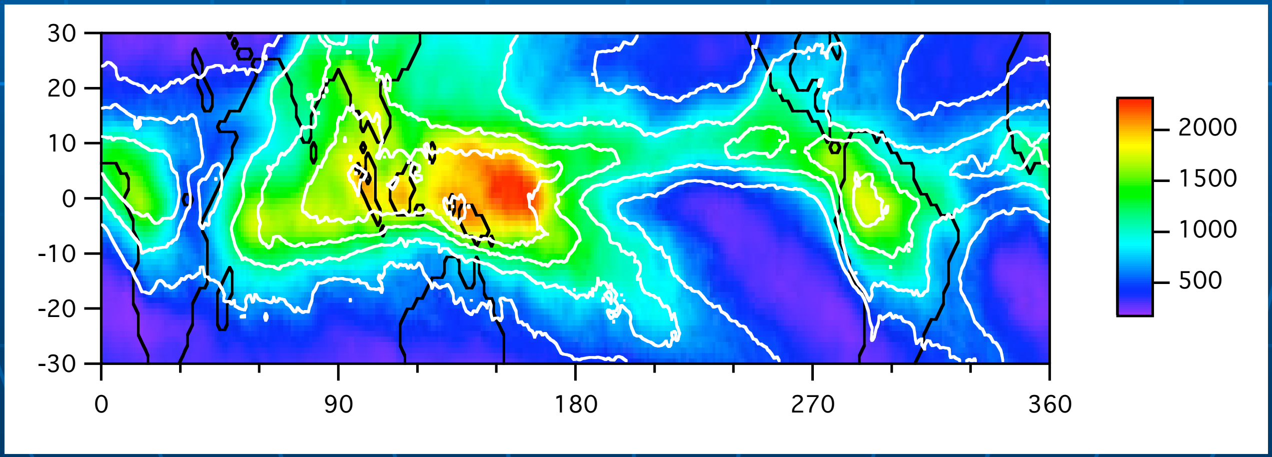
AIRS Supports Water Vapor Transport Studies

- "A comparison of AIRS Water Vapor Measurements with simple trajectory model"
  - Andrew Dessler, Texas A&M
  - Accepted GRL 2006
  - Simple trajectory model with fixed RH limit does a good job of reproducing AIRS annual average water vapor
  - Model shows that dehydration of mid-troposphere air occurs in three latitude bands



Several Recent Publications on AIRS Cloud Products and Validation

- AIRS Cloud Top Pressure and Cloud Fraction Validated
- AIRS Useful for quantitative analyses, such as cirrus mapping and frequency
- Cirrus Particle Size and Optical Depth Retrieval in Progress

Cirrus Clouds

• Kahn, B.H., E. Fishbein, S.L. Nasiri, A. Eldering, E.J. Fetzer, M.J. Garay, and S.-Y. Lee (2006), The radiative consistency of AIRS and MODIS cloud retrievals, submitted to J. Geophys. Res.

• Kahn, B.H., A. Eldering, A.J. Braverman, E.J. Fetzer, J.H. Jiang, E. Fishbein, and D. Wu (2006), Towards the characterization of upper tropospheric clouds using AIRS and MLS observations, submitted to J. Geophys. Res.

• Yue, Q., K.N. Liou, S.C. Ou, B.H. Kahn, P. Yang, and G. G. Mace (2006), Interpretation of AIRS data in thin cirrus atmospheres based on a fast radiative transfer model, submitted to J. Atmos. Sci.

• Kahn, B.H., K.N. Liou, S-.Y. Lee, E.F. Fishbein, S. DeSouza-Machado, A. Eldering, E.J. Fetzer, S.E. Hannon, and L.L. Strow (2005), Nighttime cirrus detection using Atmospheric Infrared Sounder channels and total column water vapor, J. Geophys. Res., 110, doi:10.1029/2004JD005430.

•De Souza-Machado, S., et al. (2004), Measurements of cirrus cloud parameters using AIRS, paper presented at NASD: Remote Sensing of Clouds and the Atmosphere VIII, International Society for Optical Engineering, Bellingham, WA 98227-0010, United States, Barcelona, Spain.

Cloud Properties

"The Convective Cold Top and Quasi-Equilibrium", Chris Holloway (UCLA), David Neelin (UCLA), Accepted, *Journal of the Atmospheric Sciences*, Aug. 23, 2006

• Li, J., et al. (2005), Retrieval of cloud microphysical properties from MODIS and AIRS, Journal of Applied Meteorology, 44, 1526.

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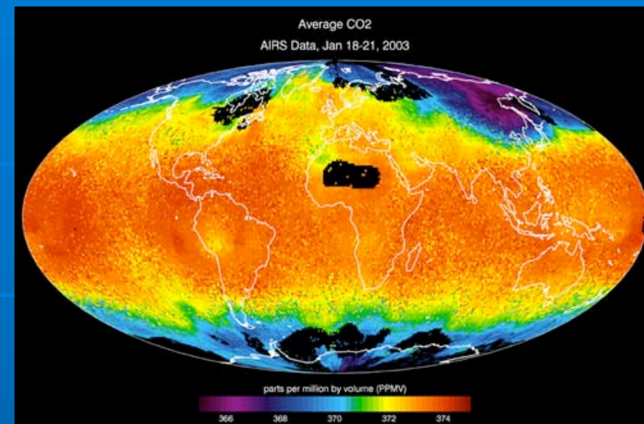
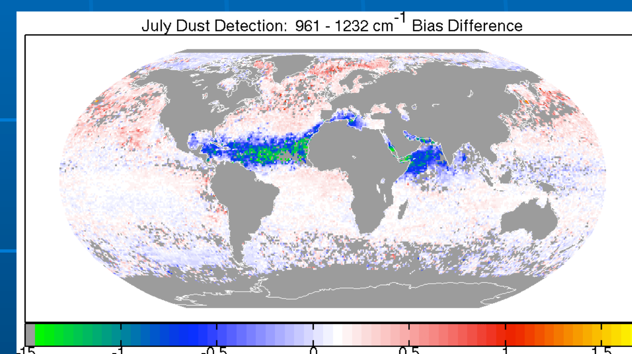
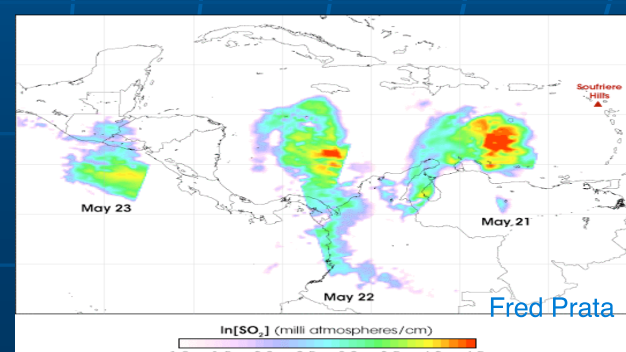
Research Products will make AIRS a "Global Greenhouse Gas" Sensor

Under development for V6

- Carbon Dioxide
  - Yogesh K. Tiwari, Manuel Gloor, Richard J. Engelen, et. al, "Comparing CO2 retrieved from Atmospheric Infrared Sounder with model predictions: Implications for constraining surface fluxes and lower-to-upper troposphere transport", JGR, VOL. 111, D17106, doi:10.1029/2005JD006681, 2006
  - Chahine, M.; Barnet, C.; Olsen, E. T.; Chen, L.; Maddy, E "On the determination of atmospheric minor gases by the method of vanishing partial derivatives with application to CO2". Geophys. Res. Lett., Vol. 32, No. 22, L22803 10.1029/2005GL024165.
  - Aumann, H. H., et al. (2005), AIRS hyper-spectral measurements for climate research: Carbon dioxide and nitrous oxide effects, Geophysical Research Letters, 32, 05806.
- Aerosols
  - DeSouza-Machado, et. al., "Infrared dust spectral signatures from AIRS", GRL VOL. 33, L03801, doi:10.1029/2005GL024364, 2006
- SO_2 , HNO_3
  - Carn, S. A., et al. (2005), Quantifying tropospheric volcanic emissions with AIRS: The 2002 eruption of Mt. Etna (Italy), Geophysical Research Letters, 32, 02301







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Recent AIRS Awards

Ramesh Kakar, NASA HQ (AIRS Program Scientist)
Exceptional Service Medal
“For his exceptional vision and sustained leadership in the NASA Earth Science Program in advancing our understanding of the behavior of the global Earth system."

John Le Marshall, JCSDA
Exceptional Scientific Achievement Medal
“Innovative use of AIRS hyperspectral data in numerical weather prediction models, demonstrating, for the first time, significant weather forecasting improvement in both hemispheres”

Annemarie Eldering, JPL
Exceptional Achievement Medal
” For combining data from the Tropospheric Emission Spectrometer on Aura and the Atmospheric Infrared Sounder on Aqua to help in elucidating the physics and chemistry of clouds and aerosols in Earth’s atmosphere ”

BAE SYSTEMS
Public Service Group Achievement Award
”Recognizing the successful design, development, calibration, and continued successful operation of the Atmospheric Infrared Sounder instrument on board the Aqua satellite.”

AIRS/AMSU Team
Russ Treadon, John Derver, Larry McMillin, Fuzhong Weng, Mitch Goldberg
US Department of Commerce Gold Medal - NOAA AIRS/AMSU Team

US Department of Commerce Awards Gold Medal to NOAA AIRS/AMSU Team

Left to right: Secretary of Commerce Carlos M. Gutierrez, Award Recipients Russ Treadon, John Derber, Larry McMillin, Fuzhong Weng, and Mitch Goldberg, NOAA Administrator Conrad Lautenbacher, and Deputy Secretary of Commerce David A. Sampson

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AIRS Science Team

Continuing Members

Chahine, M. (TL)	JPL
Aumann, H.	JPL
Gautier, C.	UCSB
Goldberg, M	NOAA/NESDIS
Kalnay, E.	UMD
LeMarshall, J.	JCSDA
McMillin, L.	NOAA/NESDIS
Revercomb, H	U of Wisconsin
Rosenkrantz, P.	MIT
Staelin, D.	MIT
Strow, L.	UMBC
Susskind, J.	GSFC

New Members

Brewster, K.	U of Oklahoma
Barker, D.	NCAR
Icano, M.	AER
McMillan, W.	UMBC
Atlas, R.	GSFC
Lord, S.	NOAA/NCEP
Barnet, C.	NOAA/NESDIS
Knuteson, R.	U of Wisconsin
Milosevich, L..	NCAR
Tobin, D.	U of Wisconsin
Mlynczak, M	LARC

International Partners

Chedin, A. (Continuing)	CNRS
Rizzi, R. (Continuing)	U of Bologna
Calheiros, R. (Continuing)	Brazil/HSB
McNally, T.	ECMWF
Saunders, R.	UKMO

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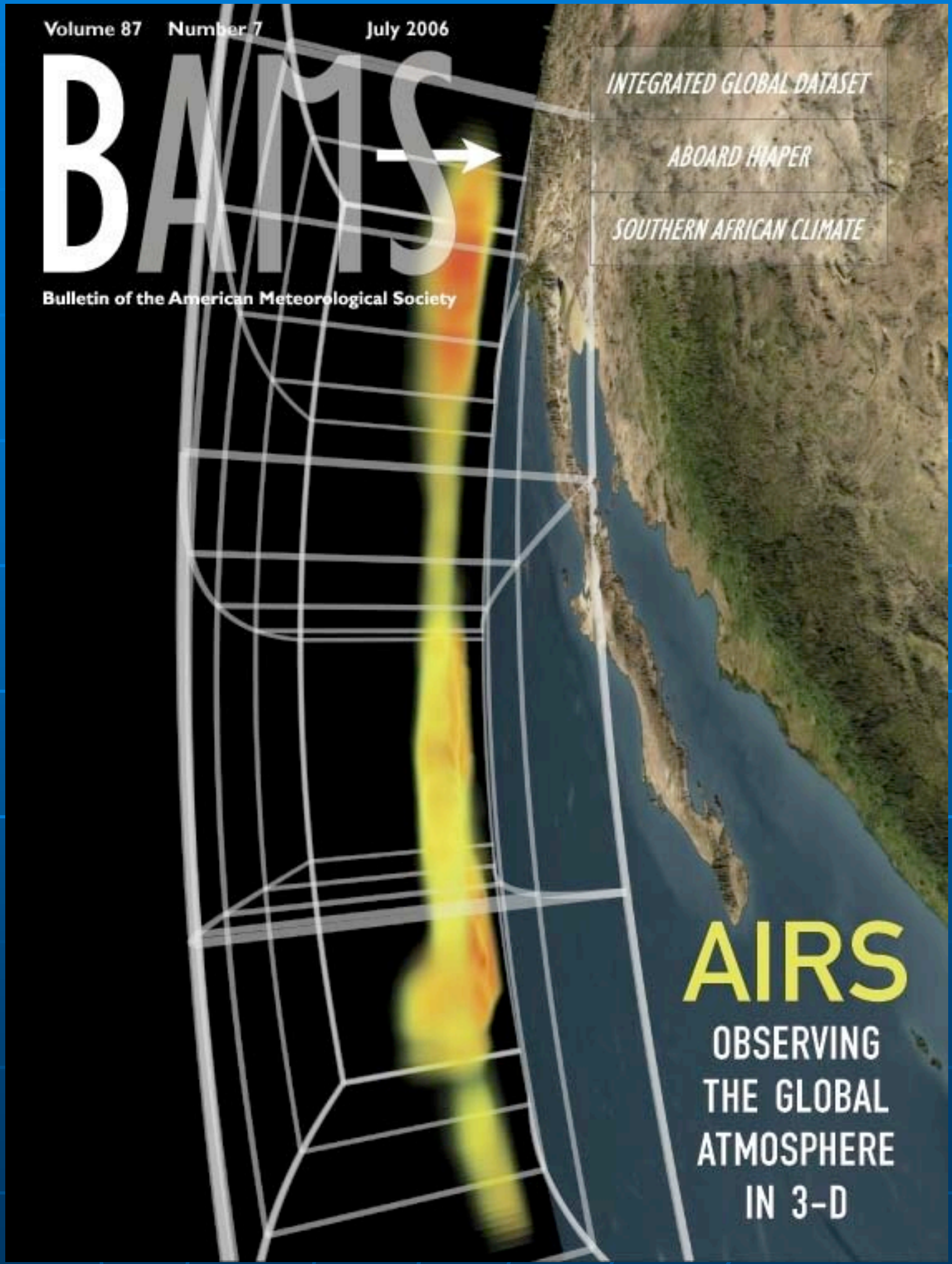
AIRS Articles Featured in the July Issue of BAMS



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AIRS Outreach

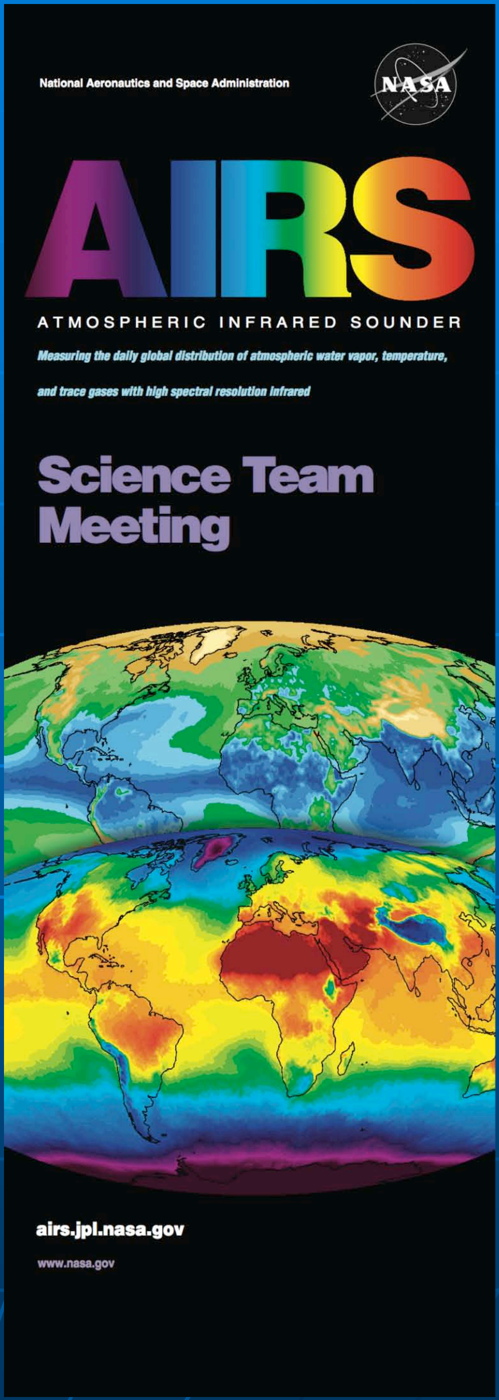
- Web Site Upgraded
  - http://airs.jpl.nasa.gov
  - New Rapid Response Capability
  - New Content Management System
  - Near Real Time data from the DAAC, daily global coverage for rapid
  - response (Level 1B, Level 2 is coming)
  - Broadcast strategies

- Postcard in Progress
  - Describes AIRS mission and data
  - Targeted to communities of interest
  - Refer back to web site
  - Distribute at conferences, etc
  - Debut at AGU

- AGU
  - AIRS presentation, video

- Discovery Science Center in Santa Ana, CA

- AIRS at the Smithsonian



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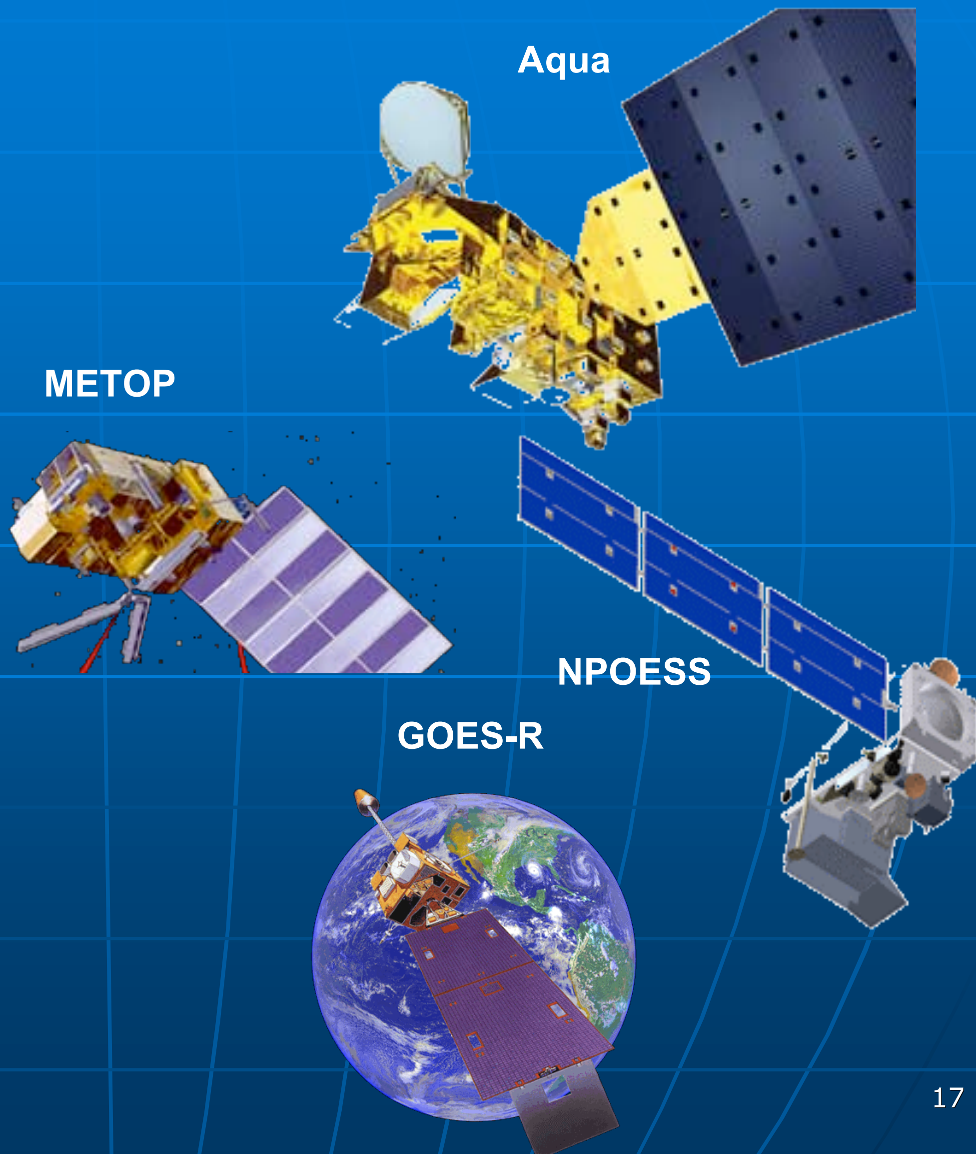
AIRS Paving the Way for Future Planned Sounders

- **Current IR Sounder**
  - AIRS on Aqua
    - 2002 Launch
    - LEO
    - 3.7-15.4 mm
    - 13.5 km IFOV
- **Planned IR Sounders**
  - IASI on METOP
    - Early 2007 Launch
    - LEO
    - 3.6-15.4 mm
    - 12 km IFOV (25 km GSD)
  - CrIS on NPP/NPOESS
    - 2009 1st Launch
    - LEO
    - 3.9-15.4 mm
    - 14 km IFOV
  - HES on GOES-R
    - 2012 Launch
    - GEO
    - 4.4 – 15.4 mm
    - 4 km IFOV

Cancelled?



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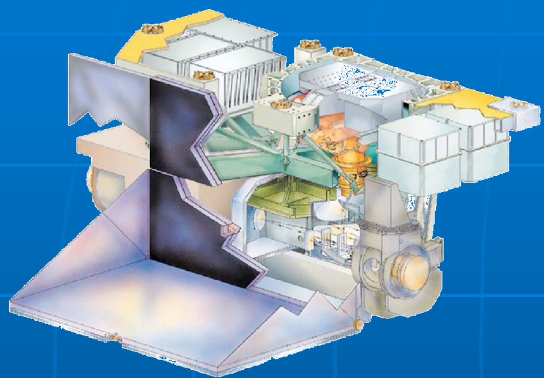
New Technology Allows ARIES to combine AIRS and MODIS Measurements into One System

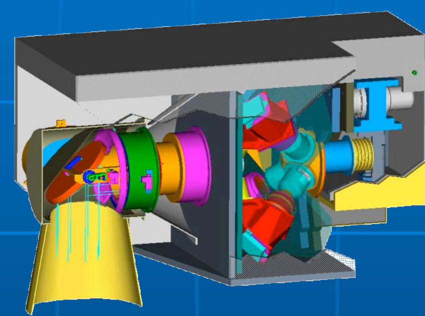
Improved:
- **Horizontal Resolution**
- **Spectral Resolution**
- **Product Accuracy**

AIRS High Spectral



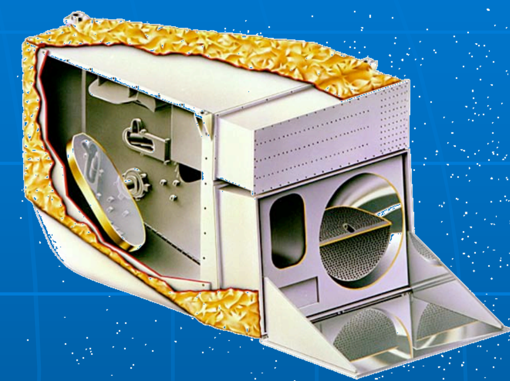
AIRS
- 13.5 km IR IFOV
- 3.7-15.4 *μm* IR
- 2378 IR Channels
- $\lambda/\Delta\lambda$ = 1200
- NEdT = 0.05 - 0.3 K
- ± 50° FOV

High Spatial / High Spectral



ARIES
-1 km IR IFOV
 0.25 km VIS, 0.5 km SW
- 0.4-15.4 *μm*
- >3600 Channels
- $\lambda/\Delta\lambda$ > 1200 (IR)
- NEdT = 0.1 - 0.3 K
- ± 55° FOV

MODIS High Spatial



MODIS
-1 km IR IFOV
 0.25-0.5 km VNIR/SW
- 0.4-14.2 *μm* IR
- 20 RSB, 16 IR Channels
- $\lambda/\Delta\lambda$ = 20-50
- NEdT = 0.05 - 0.3 K
- ± 55° FOV

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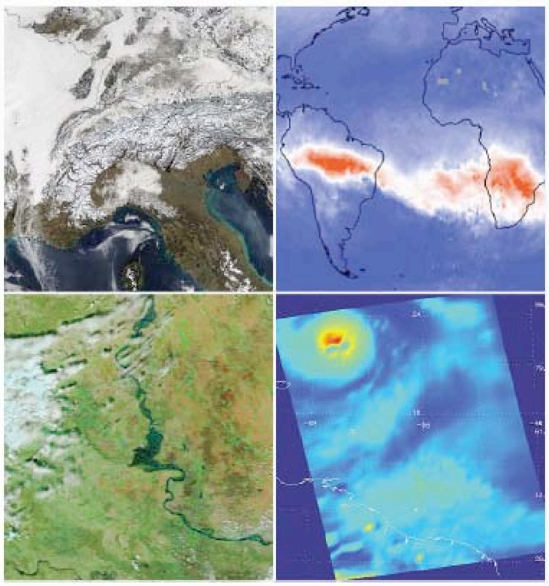
ARIES: A Future Measurement Concept to Advance Science Started with MODIS and AIRS

ARIES

Advanced Remote Sensing Imaging Earth Science Spectrometer



A space-based remote sensing measurement concept to support future earth system science

BUILDING ON AIRS AND MODIS

ARIES SPECIFICATIONS*

- ≤1km Spatial Resolution
- Daily Global Coverage
- Hyperspectral 0.4 – 15.4 μm
- Over 3000 Spectral Channels

Spectral Bands and Resolution

Reflective	IFOV (km)	λ_1 (μm)	λ_2 (μm	$\Delta\lambda$ (nm)	N_{chan}
Ocean, Land, Atmosphere	0.25	0.40	1.00	4.8	254
Snow/Ice, Cirrus, Albedo	.50	1.22	2.18	3.9	254
Emissive	**IFOV (km)**	**ν_1 (cm^{-1})**	**ν_2 (cm^{-1})**	**$\Delta\nu$ (cm^{-1})**	**N_{chan}**
Temp, CO, CO2, CH4, N2O	1.00	2100	2950	1.0	787
Water, CH4, SO2, HO3	1.00	1150	1613	0.5	999
O3, HNO3	1.00	880	1150	0.5	637
Temperature, CO2	1.00	650	880	0.5	674

3605 Channels

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ARIES Benefits to AIRS Observations

- ARIES will measure same observational variables as AIRS but at 1km Spatial Resolution
- Water Vapor
  - ARIES will do for water vapor what AIRS did for temperature.
  - ARIES will measure the high spatial variability of water and improve accuracy in the observation of this key greenhouse gas
- Temperature
  - Improved resolution observations needed for higher resolution fvGCM and severe weather prediction
- Trace Gases and Aerosols
  - Higher spatial resolution aids identification of sources and sinks.
  - More clear observations per unit area
- Clouds and Aerosols
  - Higher spatial resolution = higher accuracy
- Surface Properties
  - Less variability in each pixel improves surface temperature and emissivity retrievals

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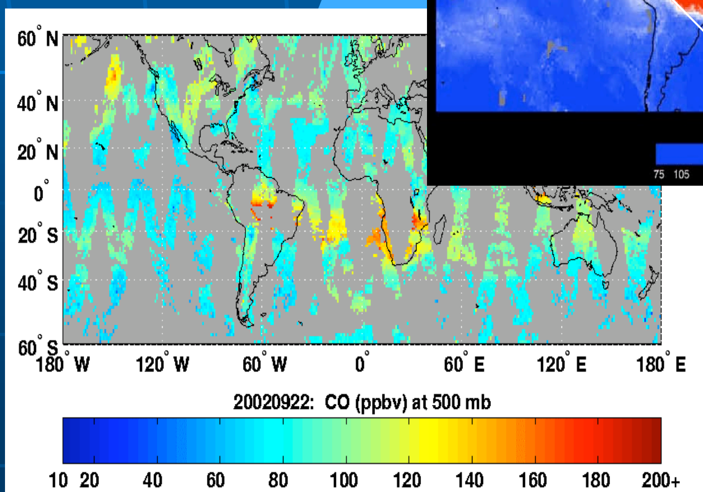
ARIES Brings AIRS Global Science Investigations to a Regional Scale

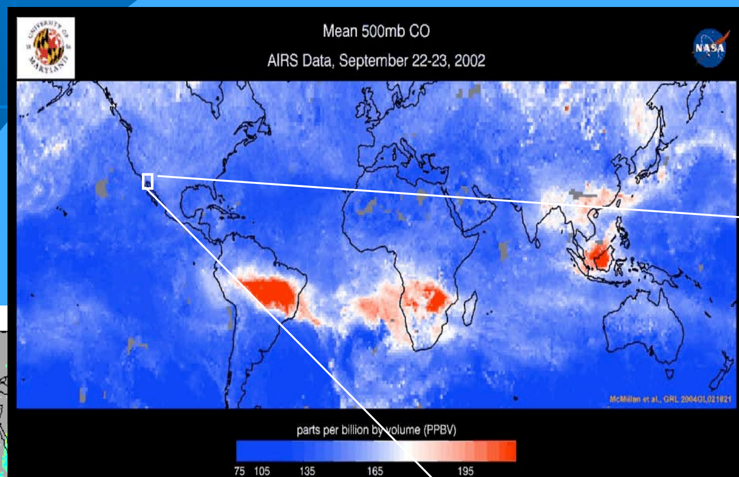
Global Carbon Monoxide Observations
Past, Present and Future

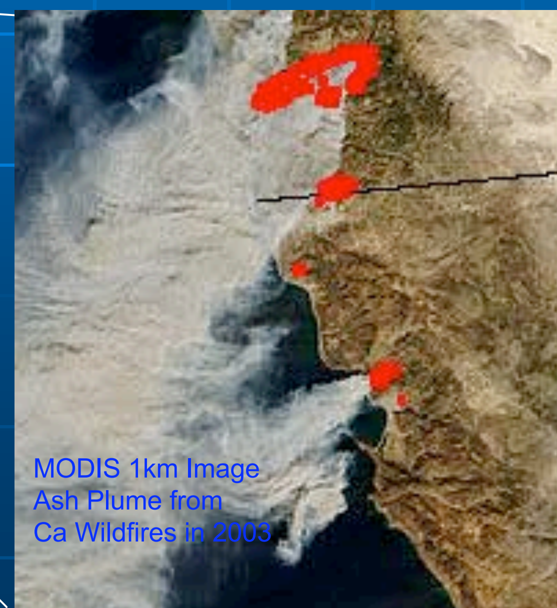
Past
MOPITT
Gas Cell
22 km IFOV
Monthly Global

Current: AIRS,
Grating,
15 km IFOV
Daily Global

Future
ARIES
1 km IFOV
Daily Global







ARIES Complements Other Missions
Don't Leave Earth Without it!

In addition to advanced AIRS/MODIS like observations, the following missions will benefit from ARIES:

- Atmospheric Correction for Temperature and Water Vapor
  - InSAR: Interferometric Synthetic Aperture Radar
  - LAS: Laser Absorption Spectrometer for CO_2
  - TIR: ~30 m Thermal Surface Measurements
- Complementary Atmospheric Composition
  - CAMEO: SMLS/TROPI: Scanning MLS + Advanced OMI
- Complementary High Accuracy Water Vapor Profile
  - GPM: Global Precipitation Mission

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Summary and Conclusions

- AIRS and AMSU Running Smoothly
- Spacecraft resources indicate enough fuel till 2015
- Complete collection of V4 online
- Final stages of V5 build
  - Includes Ozone Profile, CO and CH4
- Expect complete collection of V5 online in Summer 2007
- New science papers released addressing, climate modeling, clouds and water, composition and aerosols.
- 42 Peer reviewed publications in 2006; including cover of BAMS
- AIRS Paving the way for IASI, NPP/NPOESS CrIS and GOES-R HES in the US
- ARIES will allow science initiated on AIRS and MODIS to advance through improved spatial and spectral resolution observations.
- Keep up the good work team!